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OUTBREAKS OF THE DUTCH ELM DISEASE IN THE UNITED STATES

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INTRODUCTION

The first discovery of the Dutch elm disease in the United States was made in Ohio in 1930. All of the disease found in Ohio has been eradicated. However, the disease was identified from New Jersey in June 1933, and subsequent scouting has revealed over 3,800 diseased trees in contiguous areas in New Jersey and New York, 23 in adjacent Connecticut, and 1 in Baltimore, Md.

The main purpose of this publication[1] is to acquaint shade-tree owners, foresters, arborists, nurserymen, and others working with trees with the menace of the disease, and to stimulate them to forward specimens from unhealthy elms to State or Government laboratories for diagnosis, so that the distribution of the disease may be ascertained and control policies formulated at once to meet the situation.

Information on the disease in the United States is limited to a relatively brief experience, and relevant facts reported from Europe have been added.

IMPORTANCE OF ELMS IN THE UNITED STATES

The American elm is one of the most important shade trees in this country. For example, five cities in northern New Jersey reported a total of nearly 50,000 elms, representing many thousands of dollars invested in planting, care, and real-estate values. In many places in the New England States, which are now directly exposed to the threat of the Dutch elm disease, priceless elms make up the majority of the shade trees. Elms are also valuable as shade trees throughout the Midwest and in many places in the South, and are being used extensively in some cities on the Pacific coast.

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[1] This circular supersedes U.S. Department of Agriculture Circular 170, The Dutch Elm Disease.

They are important in mixed hardwood forests from the Great Plains to the Atlantic Ocean. The six States leading in the production of elm lumber are Wisconsin, Michigan, Indiana, Tennessee, Arkansas, and Louisiana.

SUSCEPTIBLE SPECIES

The only known hosts of the Dutch elm disease are the elms and the closely related tree genus *Zelkova*. In Europe nearly all species and varieties of elm that are grown extensively and that have been exposed to the disease appear to be susceptible.

There is considerable variation in the degree to which the various species of elms are affected by the disease. The common American elm (*Ulmus americana* L.), the most valuable species in this country, is severely attacked both here and abroad. There are six recognized native species of elm in the United States (*U. americana*, *U. fulva*, *U. alata*, *U. thomasii* (*racemosa*), *U. serotina*, and *U. crassifolia*), and in the limited tests in Europe all have been reported to be susceptible. Several Asiatic species, including *U. pumila*, *U. pumila pinnato-ramosa*, and *U. parvifolia*, are resistant to the disease. They are not immune, however, and may possibly act as carriers. *U. foliacea dampieri*, *U. glabra fastigiata*, and *U. hollandica vegeta* have been recommended for street planting under European conditions because of their reported resistance to the disease. There is a certain amount of disagreement in published reports regarding the susceptibility of some species, but it is possible that this may be due to the variability of strains within species.

THE DISEASE

DISTRIBUTION

The Dutch elm disease has been reported from Europe and North America but not, so far as known, from any other continent. Its original home is not known, but it was first noticed in the Netherlands in 1919, and since then it apparently has spread rapidly over practically all northwestern and central Europe and south to Italy. It has been reported from the Netherlands, Belgium, France, Switzerland, Italy, Austria, the Balkan States, Poland, Germany, Czechoslovakia, Norway (probably erroneously), and England, where it appeared in 1927. Its wide range in Europe indicates that it is active under a variety of climatic and soil conditions.

It has now been discovered in the United States in four distinct localities, which probably represent separate introductions. Eight diseased trees have been found in Cleveland, Ohio, and one in Cincinnati, and one tree in Baltimore, Md. The major infection discovered to date, however, centers about the metropolitan district of New York City and, so far as known at present, is included in an area circumscribed by a radius of approximately 40 miles, having the tip of Manhattan as its center.

No cases of the disease were found in a limited survey, made in the latter part of the summer of 1933, of port cities of Virginia and Louisiana through which European elm logs are known to have entered, nor in a more extensive survey in parts of Maine, Massachusetts, and Pennsylvania.

SOURCE OF THE DISEASE IN THE UNITED STATES

The discovery of the disease in Ohio in 1930, particularly the isolated case at Cincinnati, raised the perplexing question of how it reached the United States. No elm nursery stock had been imported since 1919, except under special permit, so it was considered unlikely that the disease entered the country through that source. Moreover, the small amount of special-permit stock that had been imported was examined and found to be free from the disease.

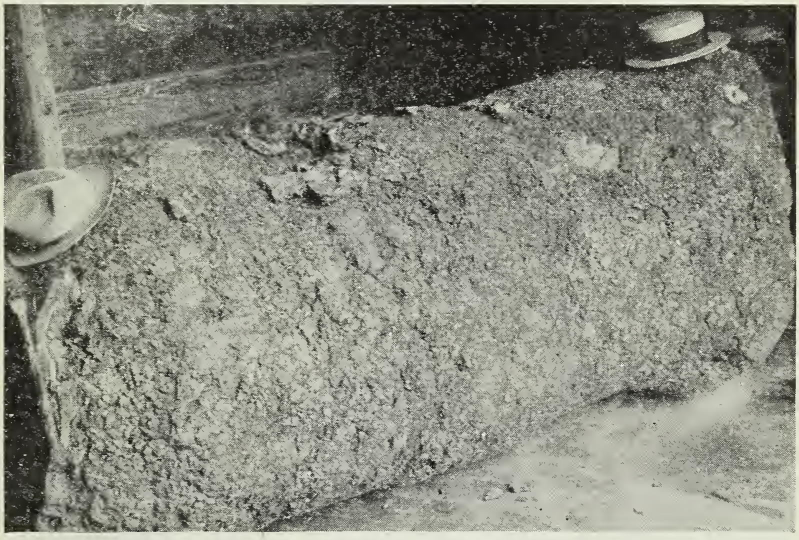

FIGURE 1.—A large burl-elm log imported from France. The fungus causing the Dutch elm disease was obtained in pure culture from this log and from European elm-bark beetles collected from it.

Burl-elm logs of European origin (fig. 1) which were intercepted at the ports of New York, Baltimore, Norfolk, and New Orleans a few weeks after the discovery of the disease in New Jersey were proved to be carriers of the fungus causing the disease. Moreover, two species of European elm-bark beetles (*Scolytus scolytus* Fab. and *S. multistriatus* Marsh.) were collected from the logs, and the fungus causing the Dutch elm disease was isolated from individuals of both species. The part these beetles presumably play in the spread of the disease is explained under the heading Transmission of the Causal Organism.

Some of the imported logs were consigned to midwestern cities, and it seems possible that the infections found in Ohio may have originated from earlier log shipments. Diseased trees perhaps may be found later in other places along the railroads over which logs were moved. In addition to the port cities where elm veneer is cut, logs are known to have been shipped to Cincinnati, Louisville, Indianapolis, Knoxville, Chicago, and Kansas City for cutting into veneer.

A quarantine regulation now prohibits the importation of elm logs or lumber with bark, and it permits their entry without bark only under special conditions which are believed to safeguard against future importations of the disease in this manner.

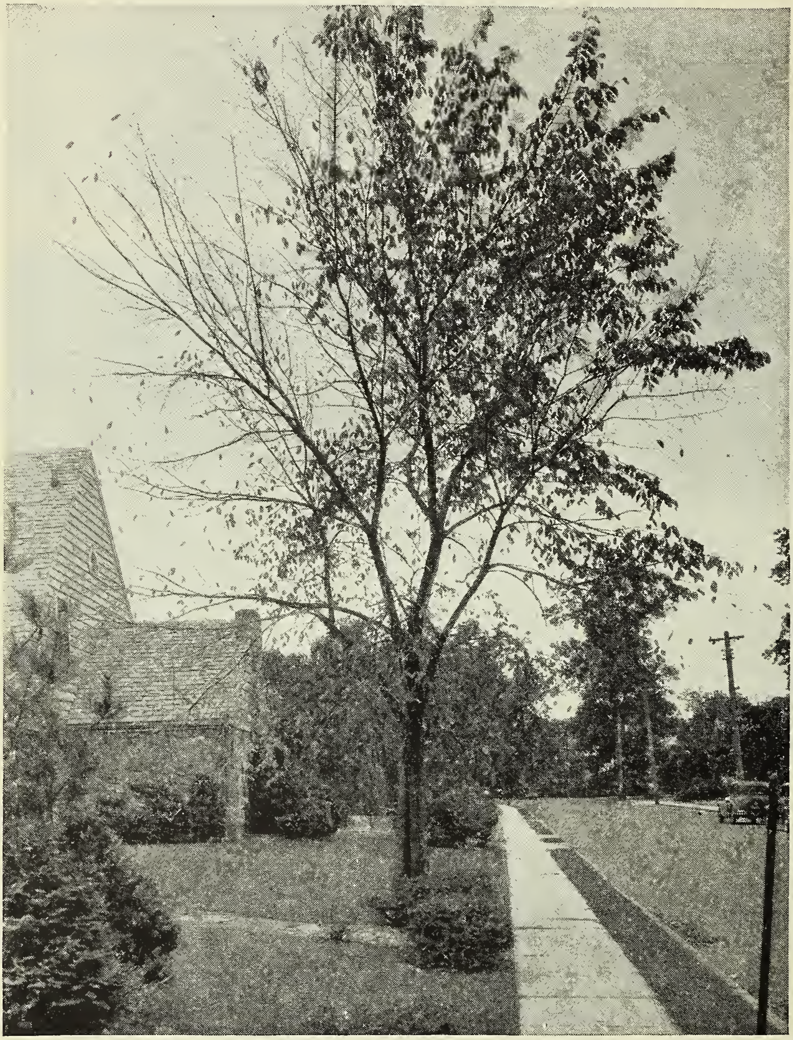

FIGURE 2.—American elm affected with the Dutch elm disease. Some leaves had wilted and others had defoliated when photographed in July 1933.

SYMPTOMS

In Ohio and New Jersey symptoms of the disease on trees in leaf have appeared first in a few instances during the latter part of May or early June. However, the disease became evident in the majority of cases later in the season and diseased trees showed foliage symptoms until the leaves fell.

In its most acute form the disease is striking and arrests the attention immediately by the suddenness and severity of the wilting of affected trees. On the other hand, trees affected with a more chronic type of the disease may escape attention because symptoms develop more gradually and are similar to those due to several other causes.

In the most acute form the younger leaves of the twigs wilt first (fig. 2), but wilting extends rapidly until the entire tree is involved. It may occur so suddenly that the leaves dry up while still green or there may be a partial yellowing or browning of the foliage before withering takes place. The dry, green, yellow, or brown leaves begin to fall soon after wilting starts. In the course of a few weeks nearly all the leaves will have dropped, but a few dead ones may remain on the twigs. If wilting takes place when twig growth is tender, some of the tips with a few leaves clinging to them may bend down to form a shepherd's crook (fig. 3).

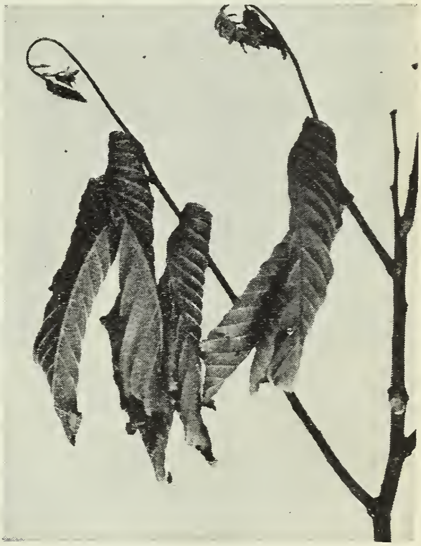

FIGURE 3.—Tender young twigs of American elm which in wilting formed shepherd's crooks. Frequently the larger leaves fall soon, leaving a tuft of small ones at the tip.

The bark on the trunk and larger limbs of such trees generally appears healthy for some time after the leaves fall, but later it dries out and dies. However, elm-bark beetles frequently invade such diseased trees soon after the leaves fall and their larvae may be found in great abundance under the bark. Their presence may lead one to suspect them erroneously of being the primary cause of the wilting and defoliation, but in such cases they are only secondary invaders that infested the tree because of the effects of the disease. If the tree was affected with the Dutch elm disease before the attack of the beetle, further confirming symptoms will be present in the wood. Cases of this type have been observed from June until late August.

In contrast to the very acute type of the disease, wilting may begin on individual branches and extend, with gradual defoliation over the tree, during the course of a few weeks or the entire summer.

Individual limbs with wilted or yellow leaves, known as "flags", are commonly associated with an early stage of a more moderate type of the disease. The yellow leaves of flags, which frequently appear first in the top of the trees, but not necessarily so, contrast sharply with normal green foliage and may be seen for a considerable distance. Late in summer the leaves often fall from those infected

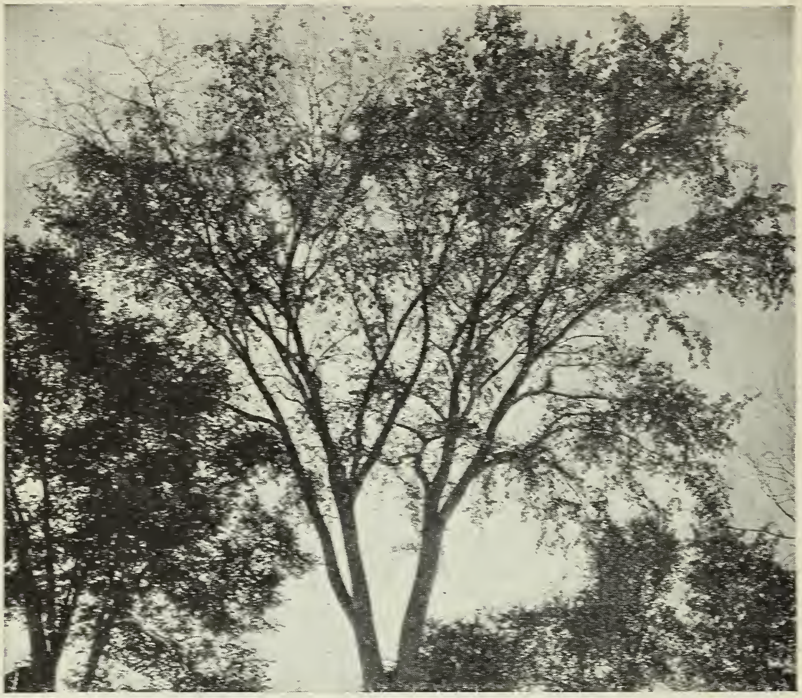

FIGURE 4.—American elm with a few branches defoliated by the Dutch elm disease. The entire tree was diseased and incipient wilting had begun throughout the crown when photographed on October 7, 1933.

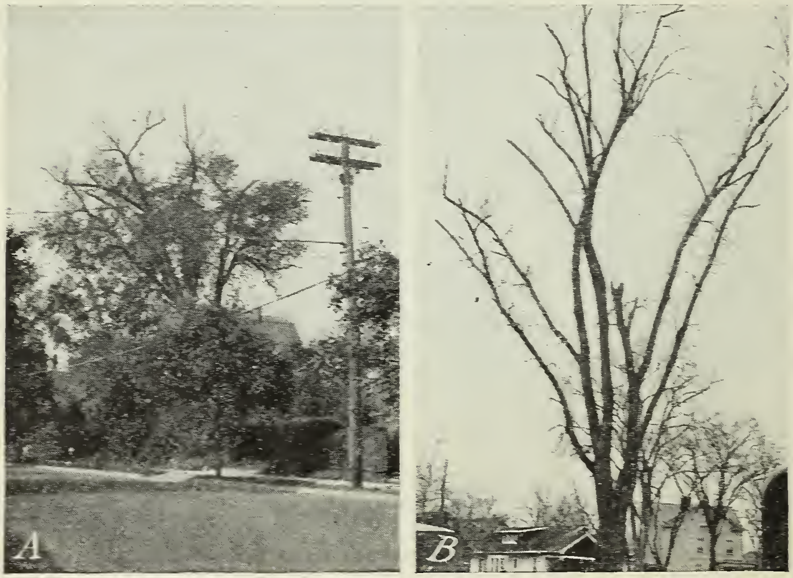

FIGURE 5.—*A*, American elm with symptoms of the chronic type of the Dutch elm disease. The tree had made poor growth and a stag-headed condition had developed. *B*, Dormant American elm affected with the Dutch elm disease. The tree had become stag-headed and numerous suckers had developed on the main limbs.

branches which had earlier shown yellow flags (fig. 4) before they fall from the rest of the tree. This differential rate of defoliation from the infected and healthy parts of a tree may be used to advantage in searching for diseased trees late in the season. However, not all yellow flags on elms are caused by the Dutch elm disease. Other diseases, some insects, and certain types of injuries may lead to their development. Their presence, however, should arouse suspicion, and a more thorough examination for the cause of the trouble should be made.

On the other hand, yellowing may not be confined to individual limbs or branches as in the case of flags but may develop gradually over the entire tree during the summer, giving it the appearance of having undergone autumnal changes too soon. In such cases, varying degrees of premature defoliation of some limbs or of all of the tree occur (fig. 4).

In a more chronic form the symptoms of disease are highly variable and develop more slowly. Affected trees may leaf out later than healthy ones or they may fail to develop leaves on one or more branches. The leaves may be small, sparse, and lighter green than normal, and may gradually fall during the summer. Annual growth is generally reduced and there may be a scarcity of small branches (fig. 5, *A*). Stag-head may eventually develop. Such trees have little to differentiate them from those weakened by other diseases, certain insect attacks, or poor growing conditions.

In winter, diseased trees have few external symptoms by which they can be recognized. However, those showing dead branches, stag-head, excessive suckering (fig. 5, *B*), those which have failed to set flower buds, or have dead leaf buds, may be affected with the disease. Trees that have recently died and are infested with bark beetles also may harbor the Dutch elm disease fungus. If one finds trees which show any of these symptoms, the wood should be examined closely for signs of the Dutch elm disease.

A brown discoloration is found in the sapwood if a diagonal cut is made through a twig affected with the disease (fig. 6). It may show in a single annual ring as a complete brown circle, a partial ring or arc, a ring of separate spots, or there may be only an occasional punctiform spot. Browning may be confined to a narrow band in either spring or summer wood, or both, or it may extend across the entire growth of an annual ring. Almost any combination of these patterns may be found in different trees or parts of trees. Discoloration may be present in more than one annual ring but not necessarily in successive rings, as one or more clear unstained rings of growth may intervene between those showing various degrees of discoloration. If the discoloration has been formed immediately under the bark in the last annual ring it may be overlooked in a casual examination of a diagonal cut; but if the bark is peeled back, exposing the sapwood, the brown streaks of varying length are evident. On the other hand, if the discoloration is confined to the spring wood and the tree has formed considerable summer wood, the brown streaks may not be evident upon removal of the bark. The streaks can usually be found in the twigs and larger parts of the tree including the roots. Sometimes, however, the discoloration is localized in a single branch.

Some trees apparently may develop considerable discoloration in the sapwood before they show external symptoms of disease.

Discoloration in the wood of diseased trees is due to the presence of brown substances which may be seen in the water-conducting tubes when a thin cross section of diseased wood is examined under the microscope, or which may diffuse from the tubes into the surrounding wood. The water-conducting vessels are more or less plugged by tyloses and the resinous materials in them (fig. 7). The

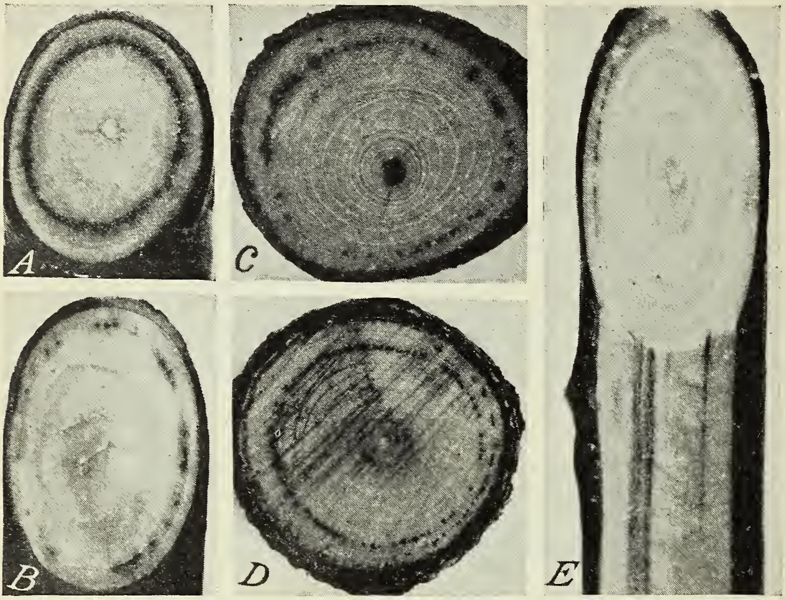

FIGURE 6.—Sections of elm wood affected with the Dutch elm disease: *A,* A complete heavy brown ring in the spring wood of the current season's growth of a 2-year-old twig. *B,* Stippled discoloration in current spring wood. *C,* Stippled discoloration in spring and summer wood of current season's growth of an 11-year-old elm branch. *D,* An 11-year-old elm branch affected with the Dutch elm disease. The eighth, tenth, and eleventh rings showed discoloration. The inside brown ring was about one-half solid and one-half stippled; the middle ring was stippled on the left side; the outer ring of discoloration immediately under the bark was almost complete. *E,* Elm twig, 4 years old, infected in the spring wood of the youngest annual ring showing a brown arc on the left and a few spots at the bottom of the diagonal cut. The spots immediately under the bark appeared as brown streaks when the bark was removed.

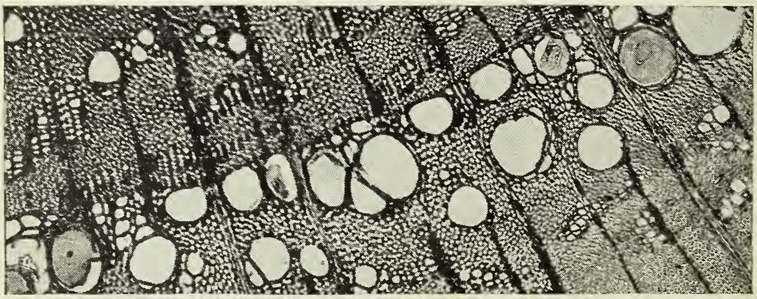

FIGURE 7.—Cross section of a group of discolored water-conducting vessels in the spring wood of elm. Some of the tubes have been almost completely plugged by the resinous substances.

discoloration in the wood is not a specific characteristic of the Dutch elm disease, however, as there are at least two other vascular parasites and probably several saprophytes that may be isolated from similar discolored streaks. At present a laboratory study, in which the fungus causing the Dutch elm disease is cultured from the discolored wood, is the only way by which the disease can be certainly identified.

CAUSE

The Dutch elm disease is caused by a parasitic fungus which lives and develops in the sapwood. It was first called *Graphium ulmi* Schwarz, but since the discovery of its ascomycetous stage it has been renamed *Ceratostomella ulmi* (Schwarz) Buisman.[2] The fungus may be isolated from diseased trees at any time during the year. It can be distinguished from other fungi which cause similar types of wilt in elm by the character of the growth produced by it in culture media and by the nature of its reproductive structures (fig. 8).

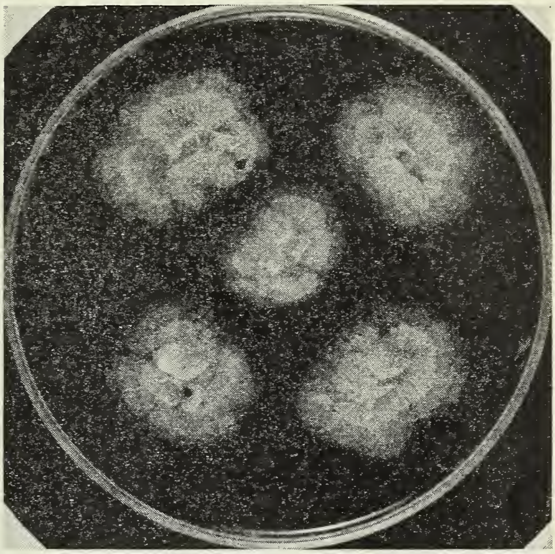

FIGURE 8.—A young culture of the fungus causing the Dutch elm disease. The fungus had grown from the small chips of discolored wood planted on the potato-dextrose-agar medium.

TRANSMISSION OF THE CAUSAL ORGANISM[3]

Several methods have been suggested by which the causal fungus might be spread from diseased to healthy trees, but the opinion now held by the majority of competent European scientists is that elm-bark beetles are the agents chiefly responsible for the rapid spread of the disease there. Two species of beetles are particularly mentioned, one of which (*Scolytus multistriatus*) is established in this country.

It was reported first in the United States from the vicinity of Boston in 1909. It has become established in Massachusetts and Pennsylvania, and is found commonly in the area in New Jersey, New York, and Connecticut in which the Dutch elm disease is known.

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[2] *Ceratostomella ulmi* sporulates acrogenously in slimy heads and also on coremial stalks (*Graphium* stage) in addition to producing perithecia, which have recently been described by Buisman. Perithecia are black, round, 105μ to 135μ; neck 265μ to 380μ with cilia; asci embedded in a slimy mass and disintegrating early; ascospores slightly curved, shaped like the sections of an orange, 4.5μ to $6 \times 1.5\mu$. Coremial stalks black, height variable up to $1{,}500\mu$, and surmounted by a mass of spores held together by a slimy substance. Coremial spores 1 to 4×2.5 to 7μ. Acrogenous conidia average $2.0 \times 4.0\mu$; shape variable. Yeastlike budding is common in cultures. Cultures on potato-dextrose agar grayish, slimy, zonate, and with abundant spores.

[3] Information on the life history of the European elm-bark beetle (*Scolytus multistriatus*) and its distribution in the United States has been supplied by William Middleton, of the Bureau of Entomology. Experiments on the transmission of the disease have been conducted cooperatively by the Department of Plant Pathology, New Jersey Agricultural Experiment Station; J. M. Walter, of the Bureau of Plant Industry; and W. D. Buchanan, of the Bureau of Entomology, U.S. Department of Agriculture.

The life history of the beetle apparently adapts it well as an agent for spreading the fungus causing the disease (fig. 9). The adults emerge from diseased, dead, or dying trees, limbs, or logs from early summer until autumn so that some beetles are in flight during all of the growing season. Upon emergence the beetles ordinarily feed in the crotches of young twigs, leaf axils, and more rarely on the sides of the twigs of healthy trees or parts of trees. They chew through the bark to the cambium region and then cut a short tunnel, which usually follows more or less the curvature of the crotch. The scars often callus, but frequently the injury is so severe that the crotch partly splits or is broken open in storms. *Graphium ulmi* has been isolated from short streaks proceeding from feeding scars of this type (fig. 9, *B*). If the beetles have been feeding on healthy trees they leave them to construct brood galleries in weakened, dying or dead trees, or in parts of trees which may have been affected with the Dutch elm disease (fig. 9, *C*).

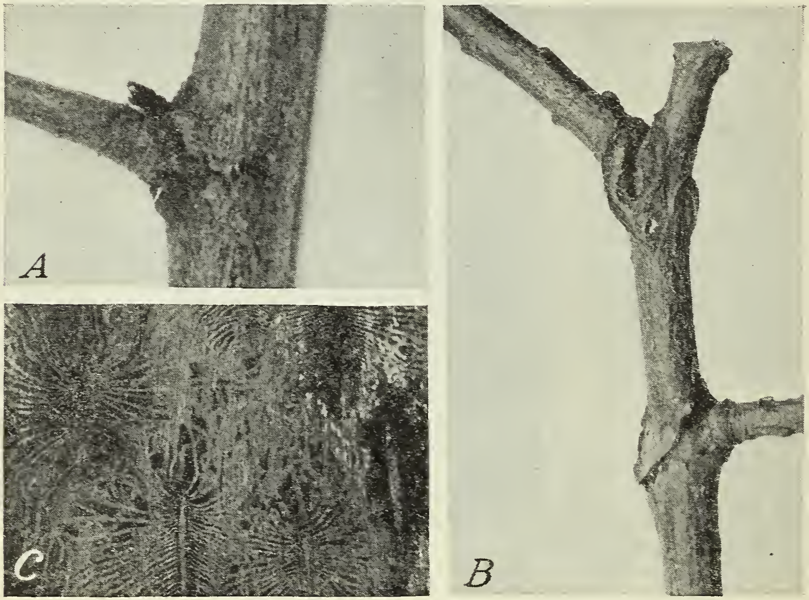

FIGURE 9.—*A*, A beetle beginning to cut a feeding channel in a young crotch of American elm. The beetle has chewed through the bark and its head is buried in the entrance. Photographed August 1933. *B*, American elm twig with two feeding scars of *Scolytus* in the crotches. *C*, Brood galleries of *Scolytus multistriatus*. Spores of *Graphium* have been found under the bark.

Trees affected with the disease may be devitalized to an ideal condition for the development of the larvae of the beetles. The emerging adults, under favorable conditions, may carry the Dutch elm disease fungus to healthy trees or to living parts of diseased trees and deposit it in the injuries that they make while feeding.

The evidence that European elm-bark beetles are chiefly responsible for the spread of the fungus may be summed up briefly as follows. Observations and experiments in Europe have led several European scientists to believe that the bark beetles are the chief agents that spread the disease there.

The smaller European elm-bark beetles were observed feeding in twig crotches and leaf axils of healthy elms, and it was found in a careful examination of over 100 diseased trees in New Jersey that all of them bore feeding scars of this bark beetle. However, no feeding scars of *Scolytus* bark beetles were found on the one diseased tree at Baltimore.

Some of these feeding scars when examined were found to have brown streaks proceeding from them, both up and down the twigs, in diminishing intensity, and it was possible to isolate the causal fungus of the Dutch elm disease from the streaks. In other cases the streaks were so numerous and had developed so far that they could not be traced to individual scars. The fungus has been isolated, also, during the winter from feeding scars from which very short streaks proceeded or in which no apparent infection had occurred.

Spores of the fungus have been found in tunnels of *Scolytus* beetles under the bark of diseased trees, and the fungus has been isolated from larvae and adult beetles.

In the absence of these beetles, the disease did not spread to any extent in Ohio. However, it was found there probably soon after it was introduced and the prompt eradication of the disease, no doubt, was effective in part in preventing its increase.

Other insects such as the beetle *Hylurgopinus rufipes* Eich., other wood borers, tree hoppers, and leaf-feeding beetles may be carriers also, but as yet no proof has been secured regarding their importance in this respect.

Woodpeckers feed on the larvae and may at least be suspected as potential carriers. Sapsuckers, because of their feeding habits, could easily bear the fungus from tree to tree, but evidence on this point is also lacking.

There is no experimental evidence to indicate that wind is an important agent in transmitting the fungus from diseased to healthy trees. The reproductive bodies (spores) are produced in masses held together by a slimy material or in flask-shaped bodies from which they emerge in a sticky mass. However, the frass of the elm-bark beetle from which the Dutch elm disease fungus has been isolated may be powdery at times and could be distributed by wind, if it were exposed by the loosening of the bark of diseased trees or otherwise. Coremia of the fungus have been observed in nature on the ends of logs cut from diseased trees and under loose bark of old logs lying on the ground.

Observations on diseased trees in the field and limited experiments indicate that wounds of some sort, such as those made by bark beetles, are essential for infections. Young trees have been successfully inoculated by cutting through the bark and placing the fungus beneath it or by injecting spores of the fungus under the bark hypodermically. Limited experiments have been made to determine whether infection takes place through leaves, but none of the trees inoculated by spraying a suspension of spores on the foliage developed disease symptoms. Infection through leaves has been reported by one European worker, but others have been unable to secure similar results. However, the fungus has been cultured from leaves into which it grew from experimentally inoculated twigs.

It is not known whether infection takes place through roots in the soil, but the fungus will survive several months in soil cultures and has been reported to cause disease readily on susceptible elms inoculated in the roots.

Trees probably become infected during the entire growing season, but limited inoculation experiments on young elms in the greenhouse and similar results reported from Europe indicate that it is more difficult to produce the disease on young trees in late summer than during the early part of the growing season. However, trees have been found in January in which incipient infections originating from feeding scars of the elm-bark beetle were present, suggesting that infection may have occurred late in the season. After the fungus has gained entrance to the tree the disease may develop in any one of several ways.

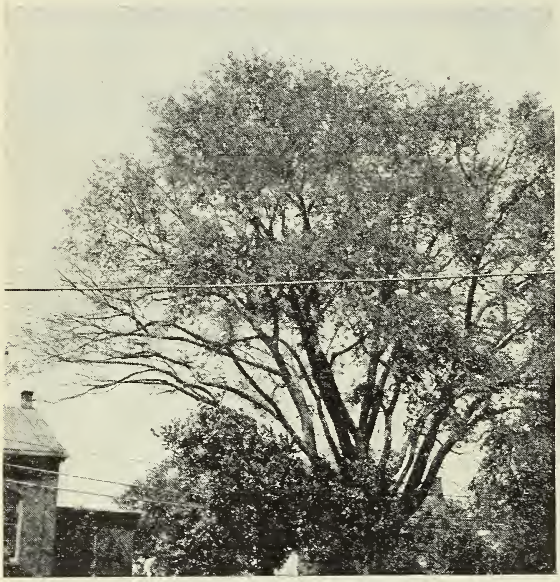
FIGURE 10.—A large American elm with a spread of over 100 feet with symptoms of the Dutch elm disease on the lower branches to the left. A month later the disease had spread throughout the crown and the tree was practically defoliated.

DEVELOPMENT

Disease symptoms may become visible on the leaves within 10 days after the tree has been inoculated, but probably in most cases a longer period of incubation is necessary before wilting or yellowing begins.

The disease may spread rapidly or slowly over the tree, depending upon many conditions not well understood. On some trees wilting throughout the crown develops almost simultaneously, followed by defoliation in a few weeks. Trees in which the disease follows such an acute course may be severely attacked soon afterward by bark beetles. The first tree discovered in New Jersey was infested with larvae of bark beetles before all the leaves had dropped, even though not more than 3 weeks had elapsed from the time the first wilting was observed in early summer. The larger larvae were in the upper branches and trunk, and the smaller ones were in the trunk nearer the ground. The disease had apparently made the tree suitable for the development of the beetle larvae, and they in turn completed its destruction. Very severe acute cases of this type do not appear to be so common as those in which the disease first develops locally and then spreads over the entire crown.

From July to October trees were observed upon which symptoms of disease appeared first on a few branches only, followed by the gradual extension of wilting, yellowing, and defoliation over the entire crown.

Complete defoliation within 4 to 6 weeks was observed on trees 50 to 70 feet tall and with a spread of branches of 50 to 100 feet (fig. 10).

The disease may kill such trees the first year or, if it has developed late in the season, may kill only certain parts. However, such trees may be weakened and may suffer further loss of limbs before the next growing season because of winter killing. Later they may develop a stag-head condition and present the appearance of chronic cases (fig. 5, *A*).

Chronic cases of the disease in which the tree gradually declines have been noted. This type of the disease may be due to reinfection of the tree or to a recrudescence of activity of fungus already present in the wood. Some European scientists have expressed the opinion that approximately 85 percent of the trees upon which symptoms reappear in successive years have been reinfected each year in which symptoms appear. However, an examination of numerous affected trees in New Jersey indicated that symptoms of disease during the current season had developed from incipient infections of the previous year.

Chronic cases may have dead limbs infested with bark beetles, and at the same time other parts of the tree may show active symptoms of the disease. They are probably centers from which the disease is spread to other trees.

However, not all stag-headed or devitalized trees in the area in which the disease is known have been reduced to that condition by the Dutch elm disease. Other factors may have caused their decline and they may have become affected with the disease subsequently.

Some infections may be confined to a single branch or limb, but cases of this type are apparently not common. More often it is found, upon examination of the wood, that the infection has already progressed into other parts of the tree which have not shown external symptoms of the disease.

Observations reported from England indicate that a relatively small number of trees that had shown symptoms of disease one year appeared normal the succeeding year. However, some of the apparently recovered trees developed symptoms of disease during the third year.

Inoculations on branches of young trees have demonstrated that the fungus may spread from one part of the crown to another in the water-conducting vessels of the current growth (fig. 11). It has also been found that the fungus may move upward in the sapwood at an average rate of nearly 8 inches a day. Such rapid extension can scarcely be due to simple mycelial growth, but it is more likely due to the dispersal of free spores in the water-conducting vessels.

There is some evidence to support this hypothesis. An analysis of results of serial cultures of infected branches indicates discontinuous distribution of the fungus in the wood. The spores are small enough to move freely in the vessels of American elm and have been found in them in sections made from naturally diseased trees. Moreover, they have been passed experimentally through a little more than 3 feet of elm branch in a few minutes. In prepared sections hyphae of the fungus which passed from one vessel to another have been observed.

The annual rings in which discoloration is found are supposed to indicate the years in which infection took place. This theory is accepted by some European workers, but the opinion has been expressed that the fungus may grow from one annual ring to another. Probably the oldest annual ring in which discoloration is present represents the year of first infection, but it is evident that the fungus may pass from one annual ring to the succeeding one.

The Dutch elm disease fungus had been isolated (January 1934) from discolored streaks in the 1929, 1931, and 1933 growth rings of living elms which showed external symptoms of disease in 1933. But attempts to isolate the fungus from the clear, apparently healthy wood between the discolored rings failed. However, further study is needed before definite conclusions can be reached.

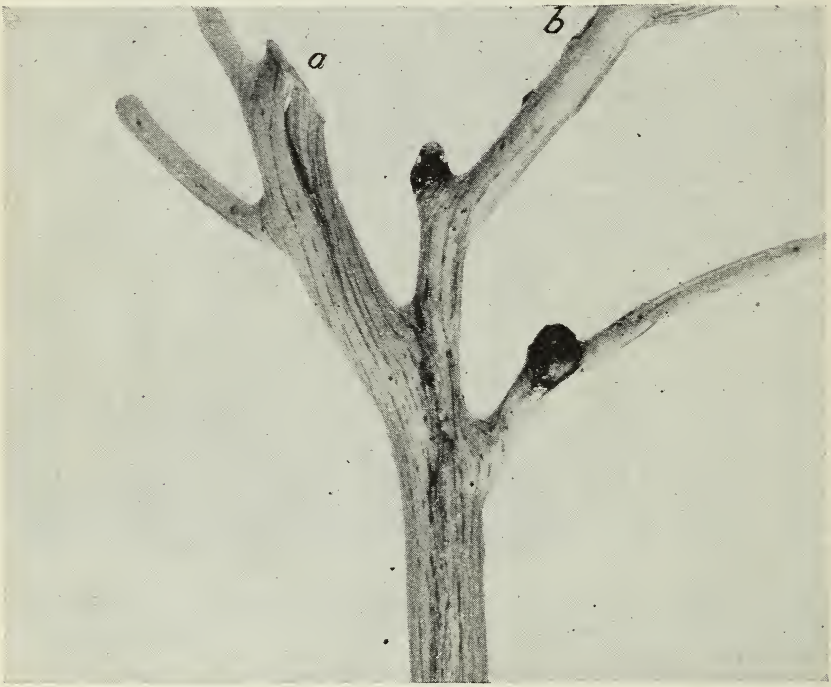

FIGURE 11.—Young American elm inoculated above points *a* and *b* on twigs from which the fungus spread to other parts of the tree. The distribution of the fungus in the crotches is indicated by the discolored streaks.

SEVERITY

There are differences of opinion among European authorities regarding the severity of the disease in Europe, but reports generally agree that thousands of trees have been killed by it, and that new cases appear each year. C. Buisman stated, in a letter to the writer in 1931, that 60 to 70 percent of the elms in southeastern Netherlands had been cut down, and that the disease had begun to spread rapidly in the northern Provinces. It has been reported that since 1920 Rotterdam and Utrecht have removed approximately 50 percent of a total of 31,000 elms affected with the disease. In the

Netherlands 26,000 elms were designated for destruction in 1932 because of the disease. Elms planted in the time of Louis XIV, at Versailles, have died recently because of the disease and have been replaced by other trees.

In England the disease has been reported as severe in some southeastern counties, where locally slightly more than 30 percent of 103 elms counted in one half mile were dead in 1932. However, the dead trees averaged about 9 percent that year in the area in which counts were made. Considering that the disease was first reported in England in 1927, this is an indication of how fast it has spread in that area. There were, however, according to the same report, districts in which the disease had made little headway.

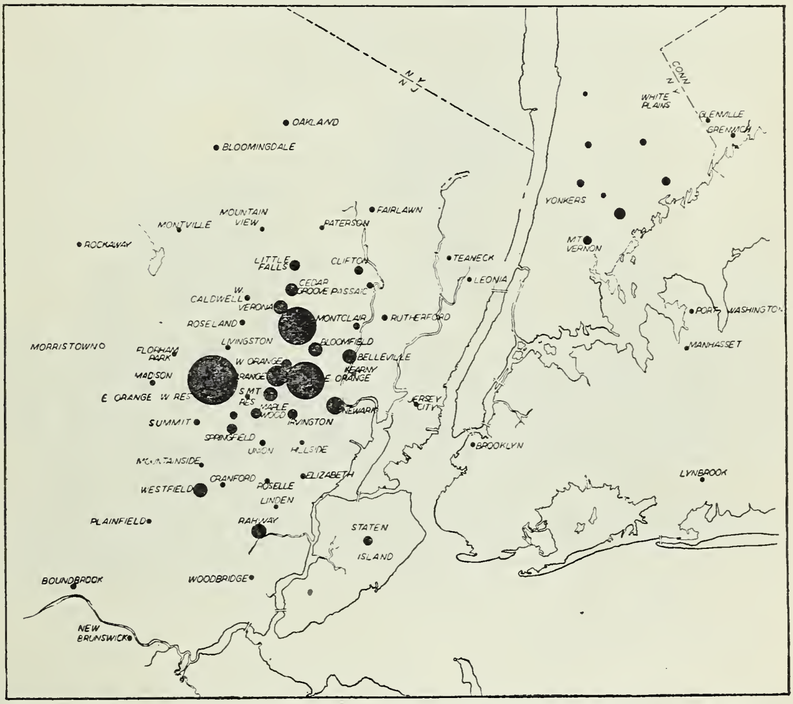

FIGURE 12.—Map of the area in which diseased trees were found in New Jersey, New York, and Connecticut from July 1933 to February 1934, inclusive. The location of the black circles indicates the approximate distribution of the diseased trees, and the size of the circles indicates their relative numbers.

Experience with the epidemic character of the disease in the United States is limited to a relatively small number of cases and to observations for one season except for those in Ohio. Only 9 diseased trees have been found there, 4 in 1930, 4 in 1931, and 1 in 1933. The one case found at Cincinnati in 1930 was not far from one of the principal railroads entering the city from the east and the 8 trees found in Cleveland were likewise close to a railroad and were restricted to an area of not over 10 square miles. Three of the diseased trees in Cleveland had discoloration in the 1929 annual ring indicating that possibly the first infection occurred then. Assuming this to be true, the disease so far as known has not spread widely in

Ohio in 5 years, probably due in part at least to its early discovery, prompt eradication, and the absence of the European elm-bark beetles. However, there probably was a slight spread of the disease at Cleveland, because 2 of the trees showed discoloration in the 1931 annual ring only.

At Baltimore, Md., a short time after the discovery of imported European burl-elm logs affected with the Dutch elm disease and infested with European elm-bark beetles, the State plant pathologist of Maryland found near the wharf a diseased tree from which the fungus causing the Dutch elm disease was cultured and identified at the Dutch elm disease laboratory. It is probable that this single case of the disease had a direct connection with an earlier shipment of European elm logs. There are few elms in the immediate vicinity and no other cases of the disease were found although considerable scouting was done by State and Federal scouts late in the season.

Nearly 1,400 diseased trees had been found to April 1, 1934, in the major area in which the disease is now known (fig. 12). Although the figure seems large, it represents less than 0.5 percent of the total elm population in the approximately 1,500 square miles in the area involved. Trees of all sizes appear to be attacked by the disease. Of the first 808 cases, 517 were less than 12 inches, 104 were between 12 and 18 inches, and 187 were over 18 inches in diameter at breast height. They were growing under a wide variety of conditions including very favorable and very unfavorable sites. Street, lawn, park, and forest trees were represented. Approximately one-half of the trees of this group were recorded as in a low state of vigor when specimens were taken from them. The others were recorded as in moderate or high vigor. Groups of affected trees in which the disease had evidently spread from a local center have been found under both forest and park conditions (fig. 13).

The exact age of the infection in the major area is difficult to determine. Some trees affected with the disease may have died and disappeared before observations began in 1933. Moreover, the determination of the age of an infection by the age of the annual ring in which browning appears is open to the objections previously explained. However, it is the best criterion upon which an estimate can be made at present.

Three trees have been found with discoloration in the 1929 annual ring from which the fungus has been isolated, but a great majority of the trees which were examined showed discoloration of the 1933 ring only.

According to available records of 916 trees in New Jersey, 790 had discoloration in the 1933 annual ring only, and the other 126 showed discoloration of one or more previous rings. In New York, from a total of 150 diseased trees studied 130 showed brown discoloration in the 1933 ring only, and the remaining 20 had it in the 1932 ring alone or in both the 1932 and 1933 rings. In both States the ratio of trees showing discoloration in 1933 to those showing it in all previous years was slightly over 6:1, an alarming rate of increase in a single year.

CONTROL METHODS

Most factors affecting the control of the disease are yet to be determined and only tentative suggestions can be offered.

A concerted effort to eradicate the disease is suggested now. The limited extent of the area in which diseased trees are known and the relatively low percentage of trees known to be diseased in this area favor the possibilities of eradication in the United States.

No general eradication program has been tried in Europe, and the attempts to control it by sporadically destroying diseased trees in various places have failed. Only a planned and sustained eradication program can adequately meet the needs of the present situation.[4] If, ultimately, eradication should be found impractical, suppression of the disease to a minimum by general cooperative action, pending an attempt to develop local control measures, would be valuable.

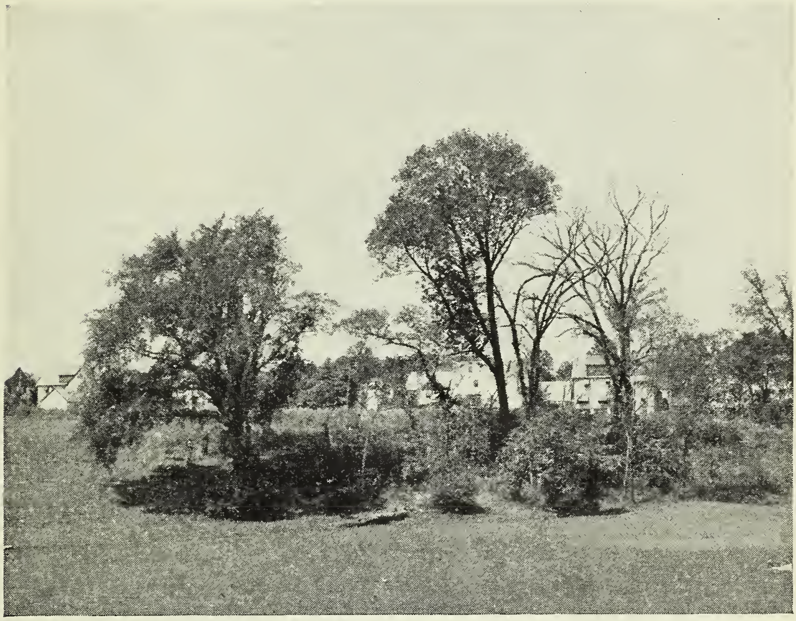

FIGURE 13.—A group of diseased elms. One large tree and several small ones were dead when the group was observed. A few weeks later when the photograph was taken several other trees had defoliated and the large tree on the left showed incipient wilting. The tall tree in the center is an ash. Photographed in August 1933.

For the present it is recommended that diseased trees be destroyed as soon as they are detected. All the wood, bark, and leaves should be burned. If parts of the tree are left, they may become sources of further spread of the disease. There may be exceptional cases in which the disease is confined locally in the top and can be removed by pruning, but such treatment should be attempted only under strict supervision and is not recommended as a general practice at this time.

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[4] The Division of Plant Disease Eradication and Control of the Bureau of Entomology has been developing plans for cooperation between Federal and State authorities, particularly of the States of New Jersey, New York, and Connecticut, for active suppression of both the Dutch elm disease and the beetle carriers. Fall and winter scouting and removal of infected trees during the late fall and early winter proved exceptionally favorable and should materially facilitate the control activities of the 1934 season.

Removal of visibly infected branches does not insure the tree against new infections nor does it prevent incipient infections from developing subsequently. The diseased parts that are removed should show no trace of discoloration at the basal end when a clean knife cut is made around the outer ring of wood. If brown streaks or spots appear on the cut end of a diseased branch, infection has gone beyond that point and the branch should be removed lower—at the ground line if necessary.

It may be practical to take trunk samples from a tree before pruning is attempted and if the disease has reached the main trunk, as indicated by the presence of typical brown discoloration in the current season's growth, the tree should be removed.

Removing and destroying diseased stumps is recommended but may not be practical as a general measure in areas in which large numbers of trees must be removed. However, in outlying centers of infection or places with only a few diseased trees, complete destruction of the stump is advisable.

If the stumps are not removed, trees should be cut close to the ground and the bark removed to slightly below the ground line to prevent their infestation with bark beetles. After peeling, the stumps should be treated with a fungicide such as creosote to prevent the Dutch elm disease fungus from fruiting on their surfaces.

It is not definitely known how much danger there may be from sprouts arising from diseased stumps. There is not sufficient evidence available to draw a conclusion on this point, and European reports are contradictory.

Spraying to control the disease directly is not effective because the fungus develops in the wood of infected trees and cannot be reached by surface applications. Results of experiments in Europe also discount the effectiveness of spraying as a means of controlling the disease.

APPEAL FOR SPECIMENS

Any control program must be based in part on the known distribution of the disease. It is therefore highly important to locate as soon as possible any new centers of infection that may exist. To that end the thoughtful cooperation of every one interested in trees is urgently requested. Specimens from diseased elms from any part of the country will be gladly examined for the Dutch elm disease fungus, and the results of the examination reported to the collector.

The specimens should show brown discoloration in the sapwood and should be taken from a part of the tree that has recently wilted or died, or that has small leaves, or from a yellow flag, rather than from parts that have been dead for many months. Sometimes, however, if only dead wood is available the disease can be identified in it, but it takes considerably longer and the success of the test is doubtful. Specimens for culture should be approximately one-half inch in diameter and 6 inches long. Six or more pieces should be securely wrapped and mailed to the Dutch Elm Disease Laboratory, Morristown, N.J., or to your State plant pathologist, together with a letter giving the exact location of the tree and its symptoms.

State pathologists, foresters, and departments of agriculture in the States in which the disease is known to occur are aware of the danger from this disease and are cooperating in the work now being done on it. However, the assistance of all tree workers and owners in locating and sending in specimens from elm trees suspected of being infected with the Dutch elm disease is earnestly requested. The territory over which the elm grows is so extensive that the only way of securing an estimate of present conditions is through widespread cooperation.

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